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SHALLOW ICE BOREHOLE LOGGER AND DEPLOYMENT SYSTEM

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1988

MANAGEMENT PERSPECTIVE

Research into global climatic variability can be conducted by extracting ice core from glacierised zones of the Earth and examining the temperature and precipitation record preserved therein. This record exists as a time series of isotopic, chemical and morphological parameters which may indicate natural or anthropogenic processes that have influenced short- and long-term trends in temperature and precipitation. Borehole instrumentation is required to measure the flow of ice around the core-retrieval site. This is then used to ascertain the core-retrieval depth and helps in the establishment of the ice core time/depth relationship upon which the analysis of the past climatic record is based. The demand for reliable measurements under harsh conditions, such as those found in oil-well and ice-borehole logging operations, has advanced the state of borehole instrument technology.

PERSPECTIVE DE GESTION

Des recherches sur la variabilité du climat mondial peuvent être menées par l'extraction de carottes de glace dans les zones glaciées du globe et l'examen des indices sur las températures et les précipitations qui y sont conservés. Ces indices prennent la forme d'une succession chronologique de paramètres isotopiques, chimiques et morphologiques pouvant révéler des processus naturels ou anthropiques qui ont influencé les tendances à court et à long terme des températures et des précipitations. L'installation d'instruments dans des trous de sonde est nécessaire afin de mesurer l'écoulement de la glace autour de l'emplacement de prélèvement de la carotte. Ces mesures sont ensuite utilisées pour déterminer la profondeur à laquelle la carotte est prélevée et aident à établir la relation chronologie/profondeur sur la carotte, relation sur laquelle repose l'analyse de l'enregistrement climatologiqe passé. La demande pour des mesures fiables dans des conditions rigoureuses, comme celles dans lesquelles sont effectuées les diagraphies de puits de pétrole et de trous de sonde dans la glace, a fait progresser la technologie des instruments utilisés dans les trous de sonde.

ABSTRACT

An improved shallow ice-borehole logging system has been developed to complement the ice-core drilling activities associated with the Climate Change and Ice-Core Chemistry projects. The system is capable of logging dry boreholes up to 200-metres deep and may be easily transported and assembled by its two operators. A number of geometric and physical parameters are measured for use in studies of glacier ice rheology and deformation. The significance of conducting glacier deformation measurements in conjunction with core retrieval is summarised with special reference to climate change research.

RÉSUMÉ

Un système amélioré de diagraphie de trous de sonde peu profonds dans la glace a été mis au point à titre de complément des activités de forage pour l'obtention de carottes de glace associées aux projets sur l'évolution du climat et la chimie des carottes de glace. Le système permet la diagraphie de trous de sonde secs d'une profondeur atteignant 200 mètres; il peut facilement être transporté et assemblé par deux opérateurs et permet la mesure d'un certain nombre de paramètres physiques utilisés dans les études de rhéologie et de déformation de les glace de glaciers. L'importance de la mesure de la déformation des glaciers conjointement au prélèvement de carottes est résumée dans le cadre particulier de la recherche sur l'évolution du climat.

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Introduction

In 1980, a borehole was drilled at the N.W. Col (5340 m.) on the summit plateau of Mount Logan, Yukon Territory, Canada. (Holdsworth, 1984). The total depth attained along the borehole axis was 103 m. and total ice depth at that time, measured by monopulse radar, is estimated at 120 m. $\pm$10 m. After the drilling (coring) procedure was completed, a spring loaded annular reaming device was introduced into the borehole and notches were reamed at approximately 5 m. intervals along the entire depth, to enable future surveys of vertical strain.

A prototype logging device manufactured by Richard Brancker Research Ltd.* (Brancker, 1980) was tested and orginal borehole diameter, inclination, notch position and temperature profile data were obtained. The original device represents the basic form of the present design and performed reasonably well in 1980. It did however suffer in its mechanical arrangements. Also, the methods used in determining its downhole position and the way in which it was deployed downhole were both awkward and subject to error (G. Holdsworth, 1981, personal communication).

The new system incorporates the same basic data transmission system but allows for the future incorporation of continuous data transmission as the device is deployed. Current needs dictated a much simpler design based on, discrete rather than continuous, sampling of geometric and physical parameters at a known depth. This method of data acquisition allows operator sensitivity to output annomalies and maintains simplicity in the overall system, which are important considerations in remote, time restricted data collection program typical of Mount Logan and other high altitude sites.

Using ice-core retrieved from Mount Logan, climate change research is being conducted. The record of temperature and precipitation, both indicators of climatic change, are preserved along the core as a time series of modulated isotopic, chemical and morphologic parameters. Much of the basis for climate

change research hinges on the recognition of natural or anthropogenic phenomena which may perturb or modulate temperature and precipitation. Radionucleid, chemical and particulate constituents resident in the ice-core, exhibit perturbations which may have influenced short- and long-term trends in temperature and precipitation. The establishment of an accurate time-depth scale for the ice-core is essential to subsequent analysis. A time-depth scale may be established by (1) A complete chemical and isotopic (stable and radio-) analysis of the ice-core or (2) A dynamic flow modelling of the firn-ice domain.

The probe's capacity to measure borehole diameter, inclination, azimuth, and temperature provides the ability to closely monitor internal glacier deformation after the establishment of a borehole. By analyzing and interpreting the deformation data, we obtain a better understanding of site specific ice rhelogy and this enables the establishment of a "mechanical" time-depth relationship which may be applied to the samples recovered from the site under investigation.

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*The use of company names in this report is for reference purposes only and does not imply endorsement by Environment Canada.

1.0) System Description:

The logging probe as described in detail in the next sections of this report is capable of measuring (1) hole diameter, (2) borehole-inclination in two planes, (3) probe azimuth orientation, (4) the position of notches pre-reamed in the borehole wall and (5) borehole wall temperature. This capability is restricted to operating in a dry borehole.

1.1) Ice-Borehole Logging Probe (ILP):

The ILP consists of a transducer control pod (including suspension point, signal cable termination and azimuth measurement section), temperature, inclination and diameter measurement sections and a battery pod. See Figure 1.

The ILP is positioned within the borehole by a six point suspension system comprised of two sets of three spring steel blades. Each blade set is hinged on both an adjustable sliding collar and a fixed collar. The blade sets are positioned along the main axis of the ILP, separated by a sufficient distance and with the blades bowed outwards, exerting a sufficient pressure on the borehole wall, to centralize the probe along the borehole axis.

Axial centralization is particularily important for inclinometry. The two inclinometers incorporated into the ILP are oriented at 90° with respect to one another and located approximately equidistant from the suspension points. The inclinometers (Schaevitz, model LSFPB-30)[3] are based on a closed loop, gravity referenced, torque-balance system and exhibit a nominal range of $\pm$30°. To provide ILP azimuth orientation a potted magnetic compass (Aanderra, model 1248)[4] is used. Its accuracy is better than $\pm$2°. The maximum inclination of the ILP before binding the compass suspension is 12° (B.L. Hansen, 1986, personal communication). The pressure exerted by the blades on the borehole wall is adjustable, although a limit is placed on the allowable inclination before centralization is sacrificed due to the weight distribution along the probe. On the other hand, too much wall pressure may impede ILP progress downhole, especially in regions of high inclination or when passing a

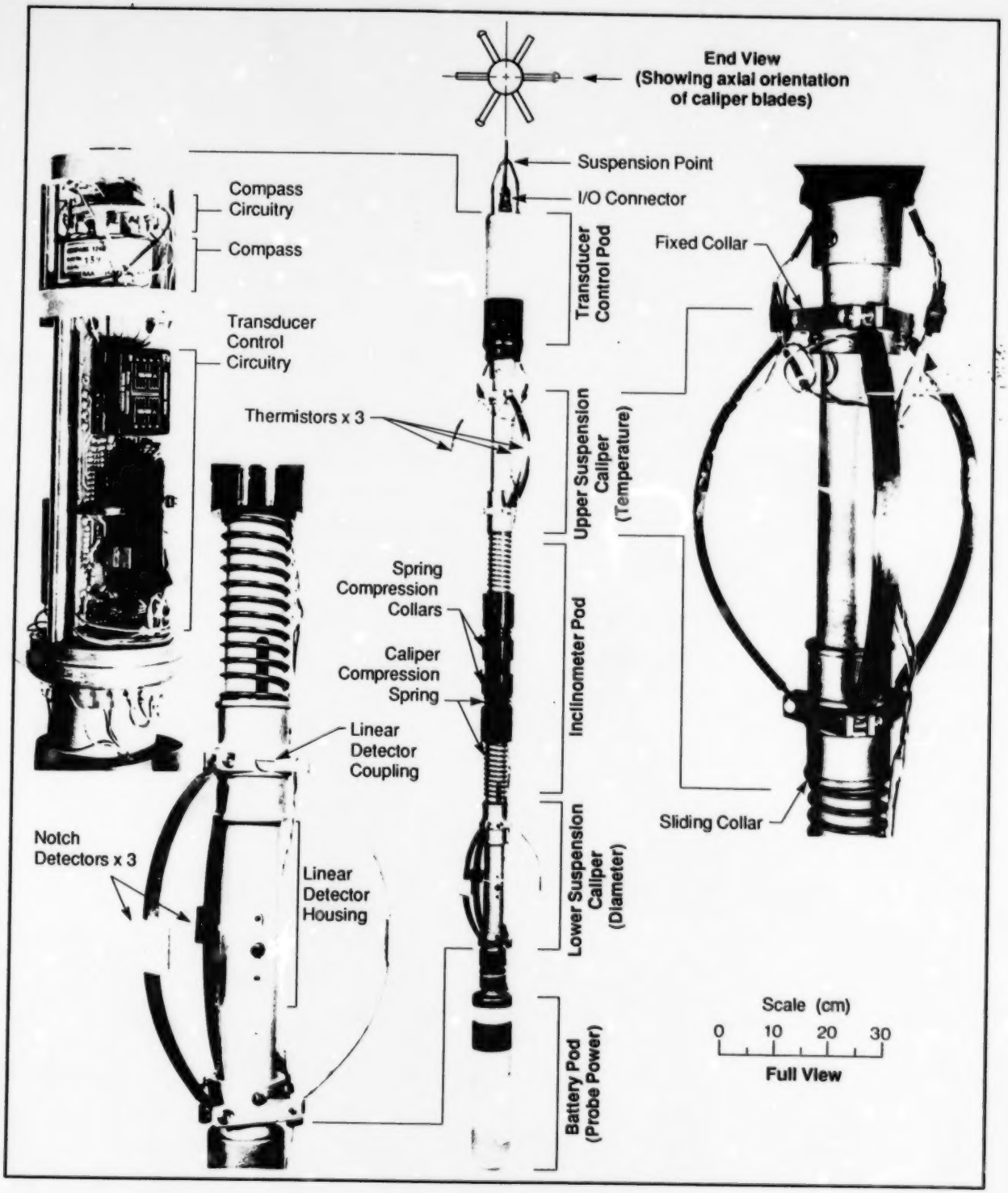


Figure 1 Ice-borehole Logging Probe

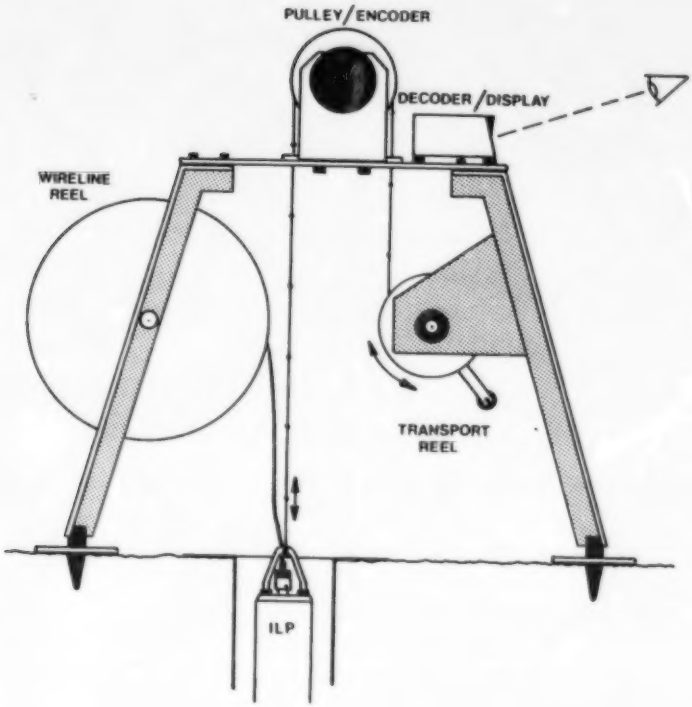
reamed notch. Weight distribution along the probe and blade pressure adjustment have been optimized to enable good results at inclinations up to 15°.

Each set of suspension blades performs another function beyond centralizing the probe. The upper set of blades (temperature measurement section) are fitted with thermistors (YSI Model #44033), thus enabling temperature profiling. The bottom set (diameter measurement section) feature notch detector protusions which are interchangeable according to the expected notch geometry. The sliding collar attached to this lower set of blades is coupled with a linear voltage detector (Schaevitz Model 1000-DCD), thus enabling diameter profiling and notch detection.

Total probe weight is 11.3 Kg while its overall height is 185 cm.

1.2) Surface Deployment Winch (SDW):

The SDW is made up of two basic elements; the support stand/wireline reel assembly and the transport reel/depth counter assembly (Figure 2). The weight of the logging probe is carried by the transport reel cable which consists of 1.0 mm stranded stainless steel beaded cable. The beads are spaced at 125 mm intervals and engage a pulley coupled to an optical shaft encoder enabling depth measurement. The shaft encoder (Sunx, REX-44-1200)[5] and the decoding logic provide a resolution of $\pm$1.0 mm. See Appendix C.



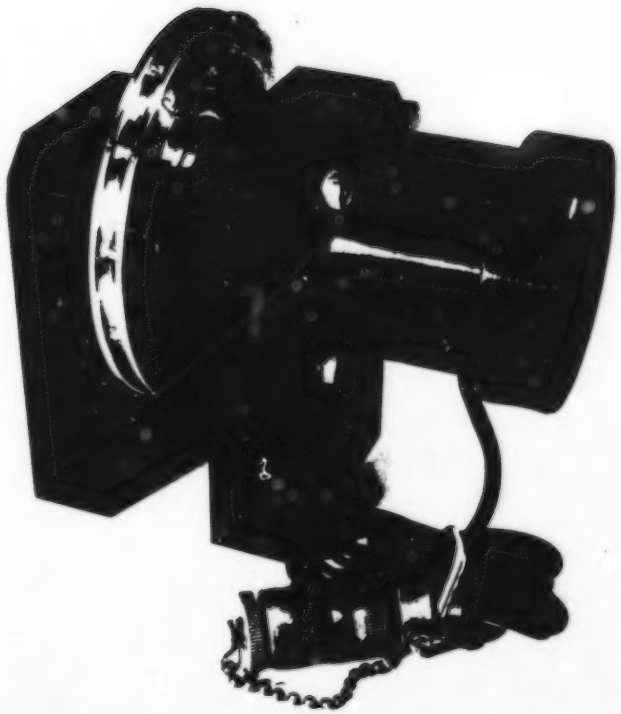


Figure 2. Surface deployment winch and the optical encoder housing assembly.

1.3) Data Transmission:

Transducer signals are individually routed to the surface via a shielded two conducter cable (Beldon 8413) through the transducer control pod on the ILP. The transducer control pod, under external commands from the probe surface-control unit (Figure 3), provides excitation to the various transducers and selects the desired transducer output for surface routing. Standard dialtone multi-frequencies are used for control purposes (Brancker, 1980). Output signals may be read manually with a good quality digital multimeter or alternately inputed into a data logger. A possible future modification could utilize the shaft encoder/decoder output in conjunction with the data logger time base to enable detailed, continuous profiling of high reponse transducer outputs such a hole diameter (notch detection) and borehole-inclination.

1.4) Circuit Modifications:

The original transducer control pod circuitry (Appendix A) was modified through the addition of a voltage divider circuit used to interpret compass orientation (Appendix B). The voltage divider principle when applied to a potentiometer, eliminates errors due to variations in signal cable resistance (temperature changes) and potentiometer wiper contact resistance. That is, depending on the nominal magnitutude of the resistance measurement made, the above resistance variations may be of the same order and resolution at certain azimuthal orientations will be in jeopardy. Thus, measuring voltage instead of resistance will yield acceptable resolution throughout the full measurement range of the compass. However, since the output voltage of the voltage divider circuit is a fraction of that applied to the potentiometer, the regulation of the total voltage applied to the potentiometer is critical. The original voltage regulator (zenor diode circuit) performed poorly when used in conjunction with the compass circuitry thus a new regulator was installed (based on a precision IC voltage source). This configuration has performed well; Appendix B includes a calibration curve for the installed compass.

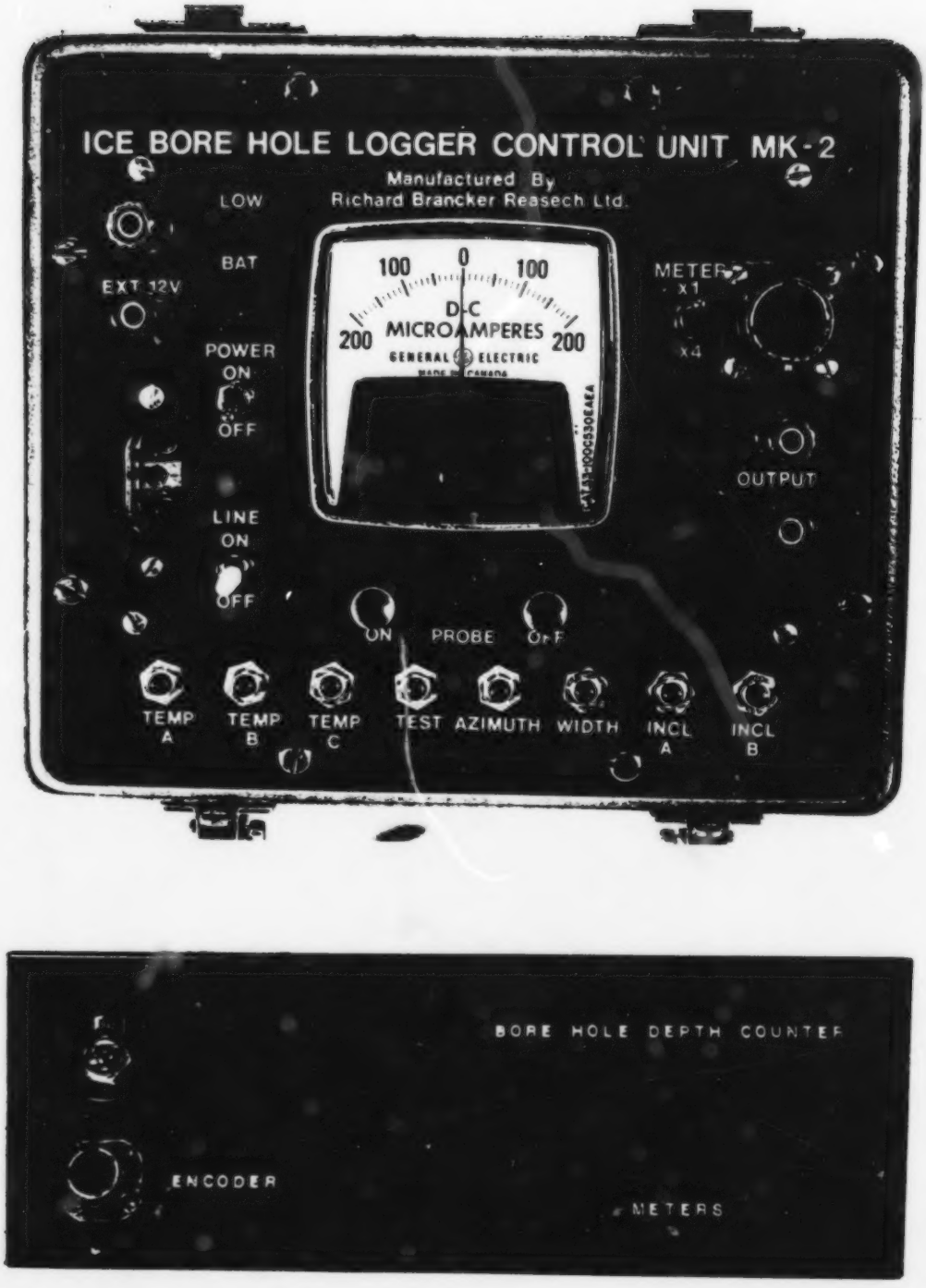


Figure 3. Surface control unit and depth-decoder circuit/display housing.

Appendix C illustrates the encoder/decoder circuitry used to establish the probe position downhole. The circuit is comprised of CMOS counters which count the output pulses provided by the incremental shaft encoder. CMOS drivers operate a six digit LED.

1.5) Power Supplies:

The probe surface control unit is powered by an internal 12V, 1.5 Amp-hr Gel-Cell battery which may be trickle charged from an AC source (117 V 60 Hz) or from an external 12VDC source. The surface-control-unit may also be powered by these external sources. A DC source of 60 to 130 ma is required depending on the transducer function selected. A solar panel has been used successfully in conjunction with the Gel-Cell battery acting as a voltage buffer. The decoder/depth display and optical encoder operate on 6 VDC at 220 ma. This is provided by a lightweight 6 volt lantern battery.

The downhole probe operates on 18 C-cell alkaline batteries contained within a teflon pod. The power requirement for proper probe function is 6 to 9 VDC at 500 ma. The loaded pod weighs 1.7 Kg and attempts are being made to incorporate a lighter more compact DC source.

Summary

The design, construction and operation of a modular shallow ice-borehole logging system has been described. Limited to operating in dry boreholes, the system is capable of measuring (1) hole diameter, 100-180 ±1.0 mm; (2) borehole inclination, 0-15 ±0.5 degrees; (3) probe azimuth orientation to within ±2.0 degrees or better; (4) the position of the logging probe and the location of pre-reamed borehole wall nothces to within ±1.0 mm along the borehole axis; and (5) borehole wall temperature as measured by thermistors, to -40 ±0.1°C.

The significance of the device in ice-core climate change studies has been shown, making reference to its use at the NW Col borehole site on Mount Logan, Yukon Territory, Canada. Cited also is the unique opportunity provided by an ice-coring operation to measure glacier borehole deformation and thus contribute to the parameterization of an accurate flow law for highly anisotropic glacier firn and ice.

Acknowledgments

We thank the staff of the Instrument and Technology Services Station, NHRI, for their quality workmanship; in particular, Mr. J. Banner in the design and construction of the required electronic circuitry. We are particularily indebted to Mr. B. Wilkinson and his staff of the University of Calgary, Faculty of Engineering Workshop, for their high quality machining and fabrication work. Suggestions by Mr. B.L. Hansen are appreciated.

We also thank Dr. T.D. Prowse, who has provided comments and suggestions during the final review of the manuscript.

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2. Brancker, R., 1980; Ice Bore Hole Logger MK2. Internal Engineering Release and Operation Manual, pp. 11. Richard Brancker Research Ltd.

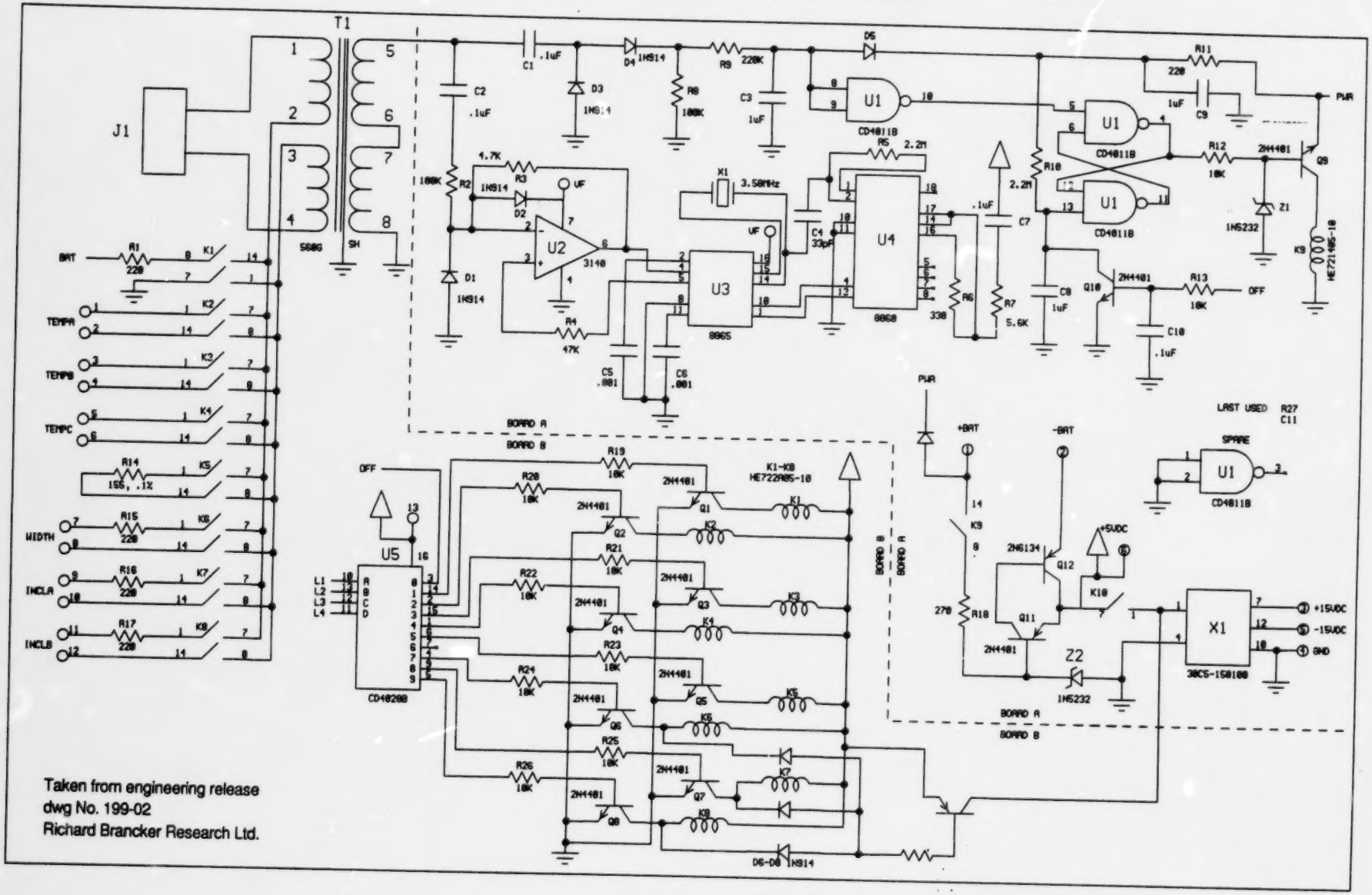
3. Schaevitz Engineering; DC Operated, Gravity Referenced Servo Inclinometers. Technical Bulletin 4505, pp. 4. Schaevitz Engineering, Camden, New Jersey.

4. Aanderra Instruments, 1980; Compass 1248. Technical Note 148, pp. 1. Aanderra Instruments, Bergen, Norway.

5. Sunx Rex, 1986; Rex 44 Series Incremental Photo Electric Rotary Encoder. Rex Series Encoder Specification Sheet, pp. 2. Sandtron Automation Ltd., Oakville, Ontario.

APPENDIX A

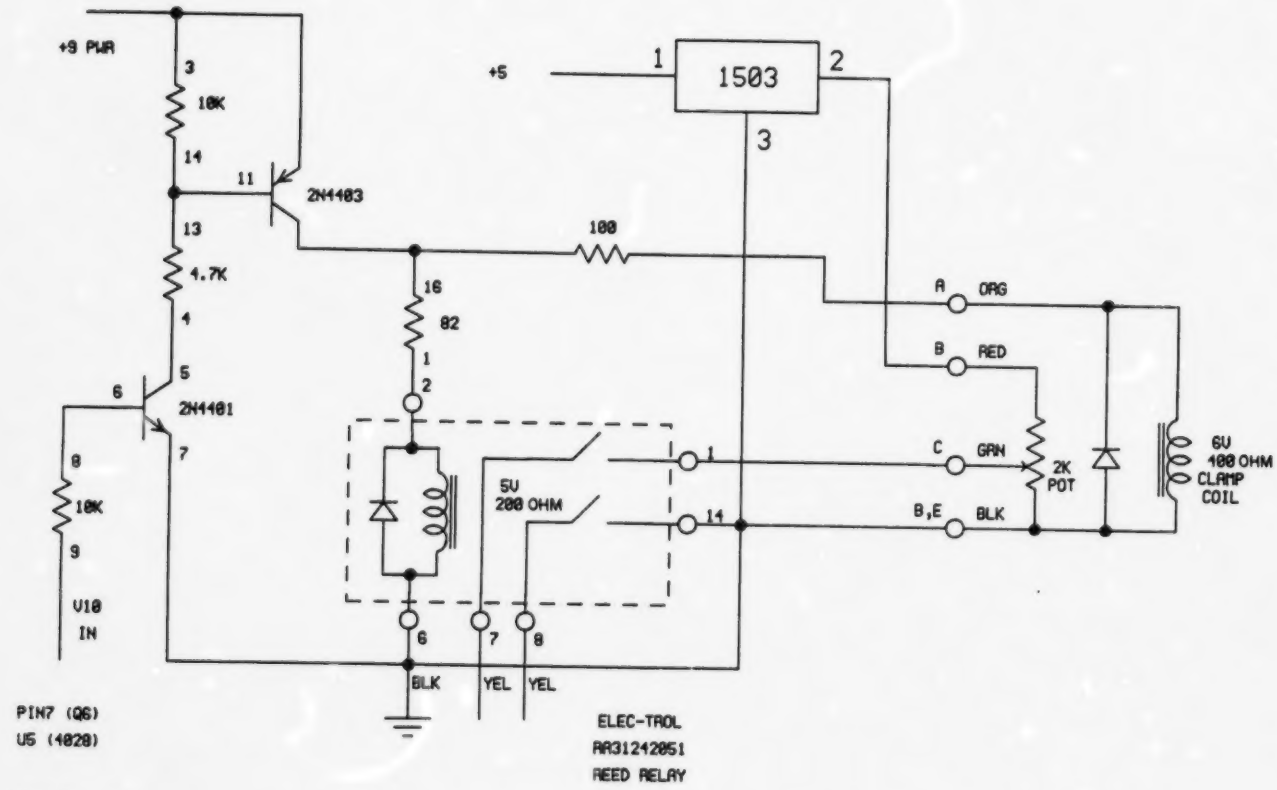
TRANSDUCER CONTROL POD CIRCUITRY



Taken from engineering release
dwg No. 199-02
Richard Brancker Research Ltd.

APPENDIX B

ICE-BOREHOLE LOGGING PROBE - COMPASS INSTALLATION



transducer
control
circuit

COMPASS 1248
AANDERAA INST.

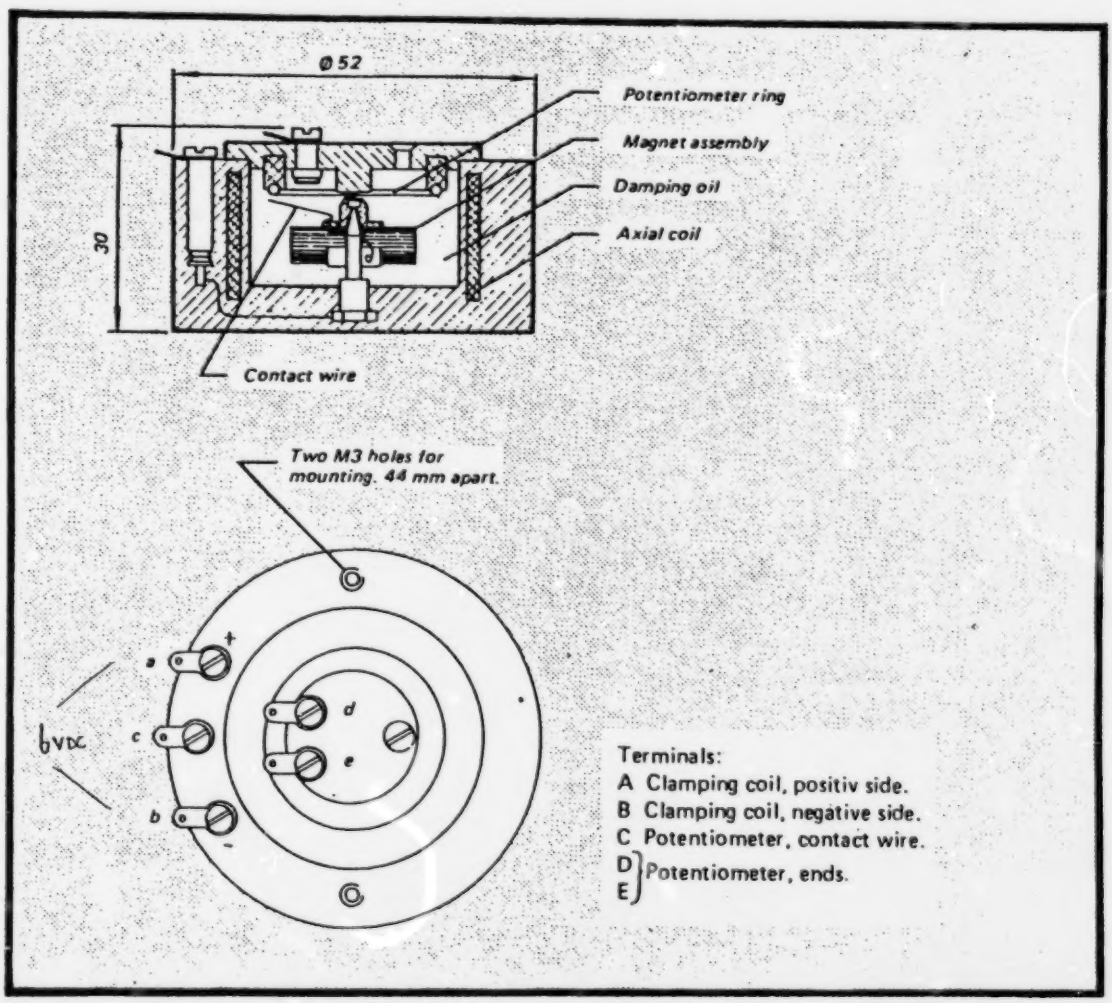
Electronics: J. Banner
NHRI - Instrument and
Technology Services Section

AANDERAA INSTRUMENTS
Fanaveien 13, 5051 Bergen, Norway

Technical Note No. 148
December 1980.

COMPASS 1248

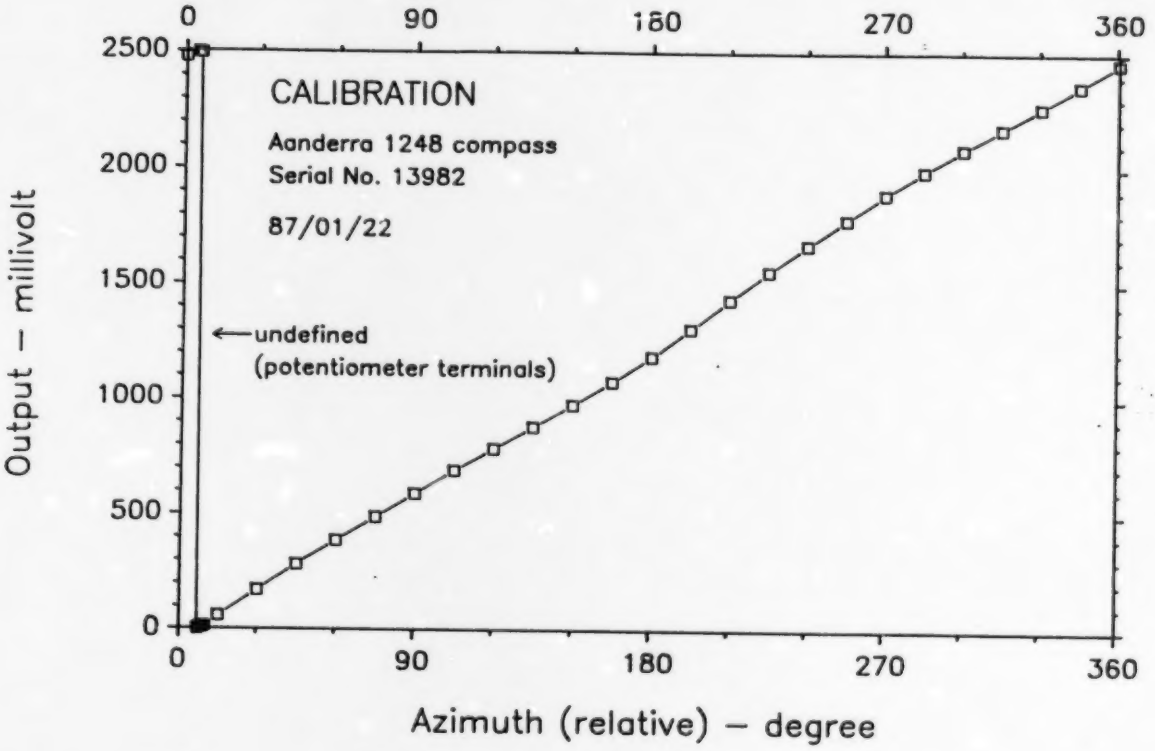
This compass was designed for use in recording current meter mod. 4. Besides application in this instrument, it can be used for many other purposes. In this compass, direction is given as a potentiometer setting. When the compass is to be read, a magnet assembly, normally free to swing, must be clamped. Clamping is done electrically by the effect of a clamping current in an axially wound coil. In the clamped condition, a contact wire on the magnet assembly will make contact with a wirewound potentiometer ring. Between readings, the clamping must be interrupted for a few seconds, in order to allow the magnet assembly to swing towards north, in case the direction should have been altered during the reading.

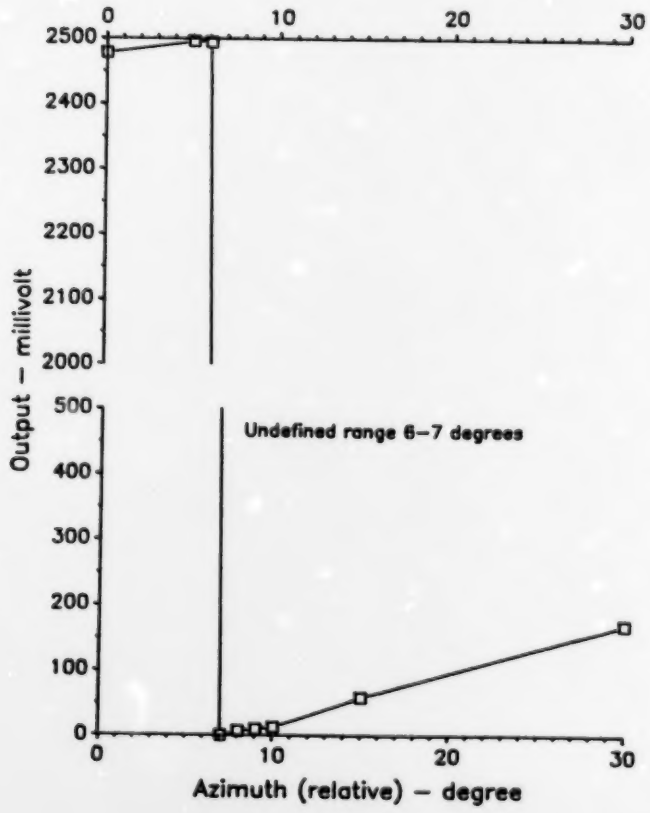


Specifications:

Clamping voltage: 6 Volts.
Clamping current: 15 mA.
Potentiometer resistance: 2000 Ω.
Allowable tilt: 12°.
Accuracy, better than: ± 2°.
Time for true reading after compass suddenly is turned 90°, is 3.5 seconds.

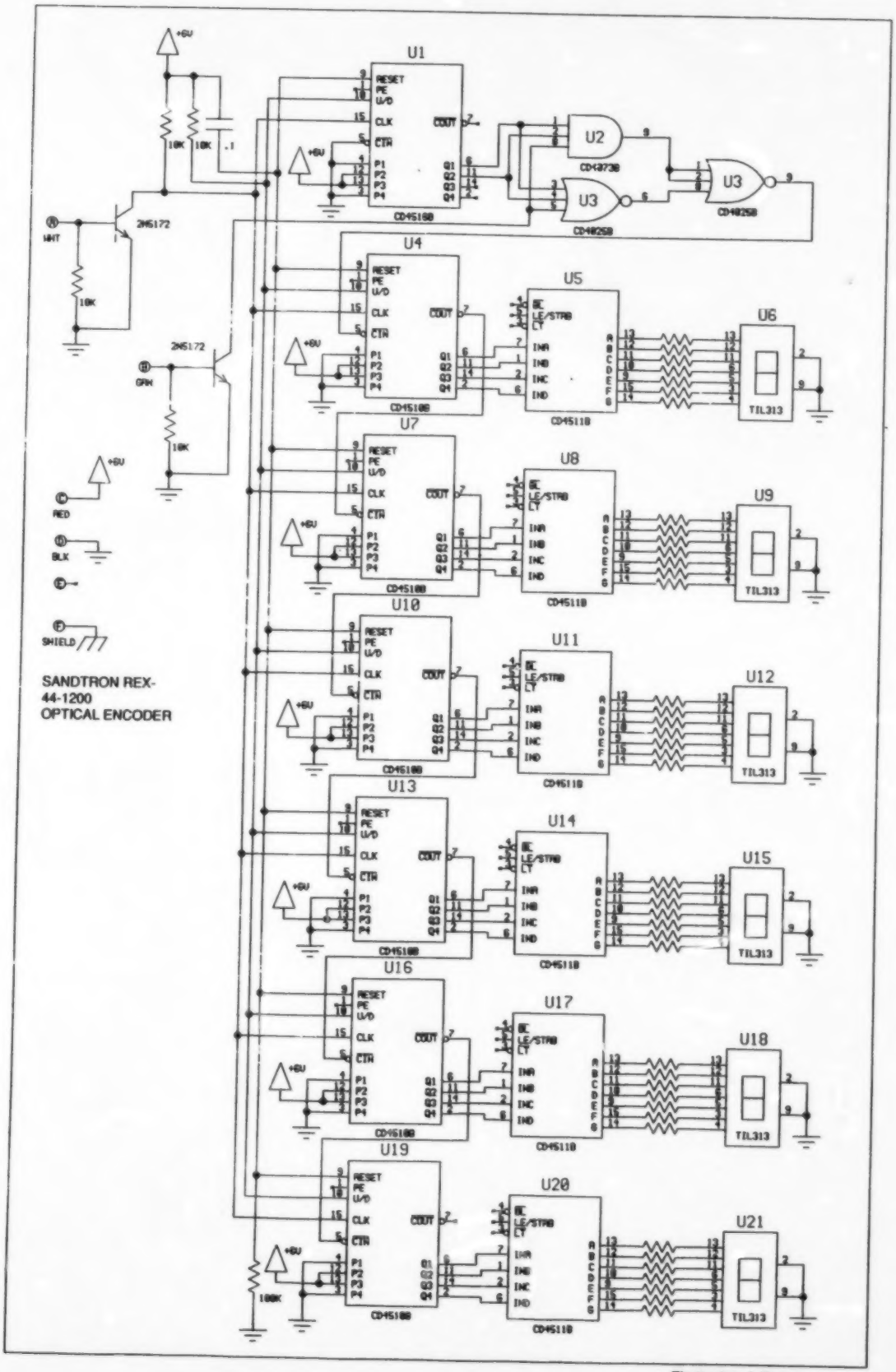
ICE–Borehole LOGGING PROBE





APPENDIX C

OPTICAL ENCODER - DECODER CIRCUIT



Electronics: J. Banner
NHRI - Instrument and
Technology Services Section
I.T.S. #86-47

MODEL NUMBERING SYSTEM

REX—32— ☐

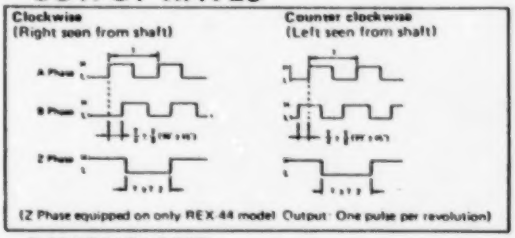
- Rotary encoder REX Series
- Outside dia. (in mm)
- Nos. of output signals (pulses/revolution)

SPECIFICATIONS

Item \ Models		REX-32 ☐			REX-44 ☐		
Power source		5 to 12V ± 10% DC					
Power consumption		Less than 50mA			Less than 60mA		
Detection type		Incremental					
Output	Nos. of output signals (standard) (pulses/revolution)	100 200 300 360 400 500	600 800	1000 1024	100 200 300 360 400 500 600	800 1000 1024 1200	1500 1800 2000 2048
	Output phase	A, B (Reversible)			A, B (Reversible) Z		
	Output mode	Rectangular wave, Voltage output					
	Output capacity	Sink current: Less than 20mA Output impedance: 2.2kΩ Residue voltage: Less than 0.5V (at 10mA)					
	Max. response frequency (Response pulse)	30kHz (30,000 pulses/second)					
	Difference of output phase	A, B Phase, Difference 90° ± 45° (T/4 ± T/8)					
	Pulse rise and fall time	Less than 2μs (with 1m-long cable)					
Activating torque		Less than 10gfcm					
Moment of inertia		Less than 1.7g-cm²			Less than 13.5g-cm²		
Axial allowable load (electrical load)	Radial	2kg	1.5kg	1kg	2kg	1.5kg	1kg
	Thrust	2kg	1kg	0.5kg	1kg	0.5kg	0.5kg
Allowable max. the number of revolution (mechanical)		6,000 rpm					
Ambient temperature/humidity		+5°C to +50°C/35 to 95% RH*1					
Stock temperature		−20°C to +80°C					
Vibration resistance		Withstands 1.5mm amplitude at frequency of 10 to 55Hz in the direction of X, Y and Z for each 2 hours.					
Impulse resistance		Approx. 50G					
Cable		1 meter of 4 (5)*2 wire conductor vinyl isolated cable, outside dia. 4.2mm					
Weight		70 g			140 g		
Accessories		One coupling, One instruction manual					

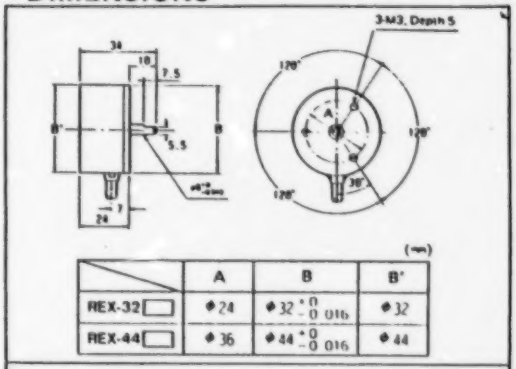
*1 : Condensation has to be avoided.
*2 : on REX-44 Series.

OUTPUT WAVES



(Z Phase equipped on only REX-44 model. Output: One pulse per revolution)

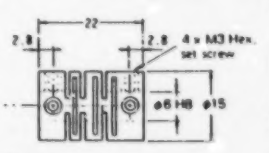
DIMENSIONS



(mm)

	A	B	B'
REX-32 ☐	φ24	$\phi 32^{\ 0}_{-0.016}$	φ32
REX-44 ☐	φ36	$\phi 44^{\ 0}_{-0.016}$	φ44

•Coupling CP6-6 (Accessories)

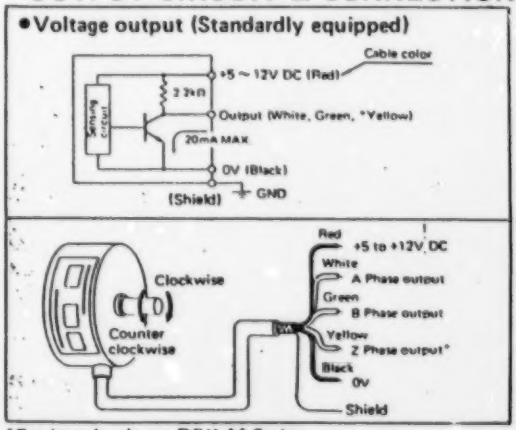


Material:
Glass-contained Polyacetals resin
Heat restivity:
100°C
Max. set screw clamping force:
2.5 kgfcm

Note:
Connectable upto 0.5 mm of coupling/shaft misalignment.

OUTPUT CIRCUIT & CONNECTION

•Voltage output (Standardly equipped)



*Equipped only on REX-44 Series.

All descriptions in this brochure is subject to change without prior notice.